

CHAPTER 5

PRETREATMENT CONSIDERATIONS

5-1. General. Before raw water is desalinated, the undesirable materials will be removed or reduced to acceptable levels. Such materials to be removed include solids, immiscible liquids, and sparingly soluble salts. Accumulations of these materials on desalination process surfaces greatly reduce efficiencies. Without adequate pretreatment, desalination facilities are destined for reduced lifetimes, shortened periods of operation, and high maintenance. The feedwater limitations for various desalination processes are summarized in table 5-1. An overview of typical pretreatment options is shown in figure 5-1.

a. Solids. Physical and chemical treatment processes will be used to remove solid materials. The level of solids removal will depend on the desalination process to be used.

(1) Settleable solids. Settleable solids are easily removed from water by gravity settling or filtration.

(2) Non-settleable solids. Non-settleable solids are removed by chemical treatment. Chemical treatment may be designed to remove not only non-settleable solids but to precipitate and remove scale-forming solids.

b. Immiscible liquids. Emulsified oil and grease are the principle sources of immiscible liquid fouling in desalination facilities. Use gravity settling and chemical treatment processes followed by a filtration system to maintain immiscible liquid concentrations within acceptable levels. To measure low levels of oil and grease, a sophisticated concentration procedure must be performed.

c. Dissolved organic contaminants. The most common organic materials, tannins and humic acids, can be removed from water by chemical treatment. Some organic materials will carry across a distillation/condensation process with the water. Pesticides and industrial organic chemicals may be difficult to remove by distillation/condensation. Reverse osmosis will usually remove the majority of the large pesticide molecules. If during pretreatment tests a non-ionized organic contaminant is not reduced to acceptable levels, then a full treatability investigation will be performed to ensure that potable water standards are met.

d. Sparingly soluble salts. As physical and chemical conditions change during desalination, some soluble materials become insoluble (precipitate). This precipitation of solid materials can foul desalination

systems through the formation of scale. Materials that precipitate easily to form scale are double-charged positive ions, such as calcium and magnesium salts. As water volume is reduced, the concentration of all ions and materials is increased. When the concentration reaches saturation, scale is formed. With alkaline earth sulfates and carbonates, the saturation concentration is reduced by increasing temperature. Ion exchange (see Chap. 8) as well as chemical treatment followed by filtration can reduce the levels of sparingly soluble salts before desalination processes. However, such a treatment system may not be cost effective, economic evaluation is needed before proceeding with detailed design. The concentration factor limits for calcium sulfates in sea water are shown in figure 5-2.

5-2. Chemical treatment. Many materials, e.g., calcium salts, magnesium salts, oil and grease, total suspended solids and some organic contaminants, that are harmful to desalination processes can be reduced to acceptable levels by chemical treatment. Chemical treatment may involve any of the following: coagulation, either with or without clarification; pH adjustment, which may influence fluoride removal; or scale inhibition. When required, degasification and secondary filtration follow chemical treatment.

a. Coagulation. Non-settleable solids and some suspended materials do not precipitate because of electrical charges on the surface of the particles. If the charges on the particles can be reduced, the particles may precipitate. Chemicals that lower surface charges are lime, alum, ferric salts, and polyelectrolytes. Evaluate each chemical used in pretreatment to determine its effect on the successive steps in the desalination process. For example, calcium present in lime can cause an increase in scale formation in distillation/condensation processes; the iron present in ferric salts can cause excessive fouling in membrane desalination systems; alum is usually the best coagulant for desalination systems. Do not use pretreatment chemicals without prior operational experience and an exhaustive actual application review. The non-settleable solids and the suspended solids in conjunction with any added coagulants will be removed by either standard clarification techniques or direct filtration. Lime softening

		Suspended Solids		Immiscible Liquids	Dissolved Organic Contaminants (Non-Ionic)	Sparingly Soluble Salts
		Settleable Solids	Non- Settleable Solids			
Distillation/ Condensation		P R E S E N T	1.0 NTU* (Some equipment goes higher.)	1.0 mg/l as extractable oil and grease*	These must all be evaluated on a case-by-case basis.	Saturated at the last-stage temperature (See Sample Problem A- 3).
Reverse Osmosis	Spiral Wound		1.0 NTU* or 5 SDI*	1.0 mg/l as extractable oil and grease for all membranes*		Saturated in the brine stream (See Sample Problem A- 3). Scale inhibitors, such as sodium hexametaphosphate, can be used to exceed saturation by two- or three-fold.
	Hollow Fine Fiber		1.0 NTU* or 5 SDI*			
	Polyaromatic Amide		3.0 SDI *			
	Cellulose Acetate		4.0 SDI*			
Electrodialysis Reversal			Less than 10 microns*	No oil and grease		Twice saturation in the brine stream (See Sample Problem A- 3). Scale inhibitors, such as sodium hexametaphosphate, are usually effective up to 4 times the saturation.
Ion Exchange			1.0 NTU			Regeneration concentration must be adjusted, if sulfuric acid is used as regenerant.

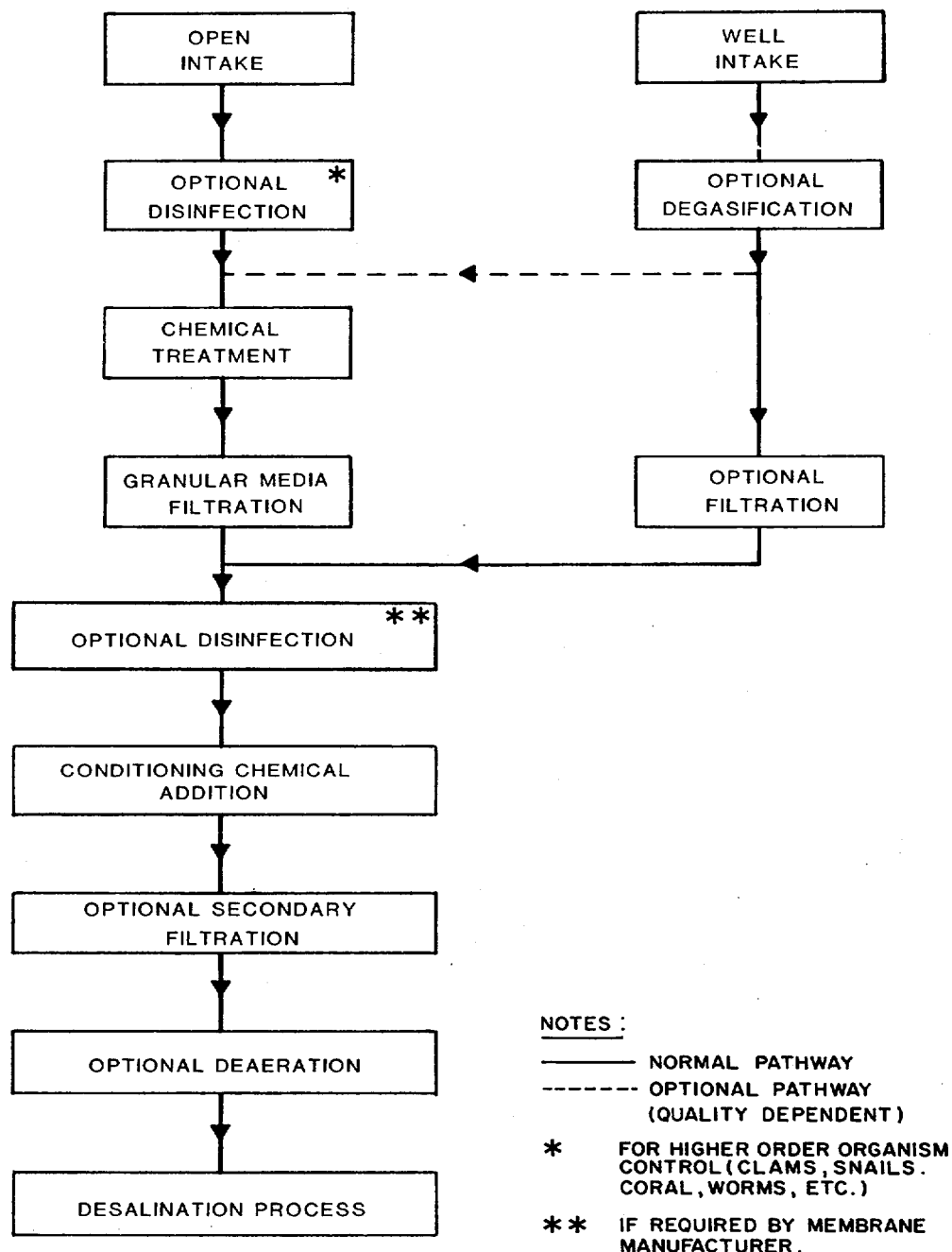
NOTES *Based upon manufacturer's guarantee

Table 5-1. The maximum allowable contaminants in the feed water used by various desalination processes

without adequate downstream filtration and pH adjustment will lead to suspended lime particles in the feed water. Lime softening will usually remove a significant amount of fluoride and may adjust the pH to the higher levels, above 7.0, where fluoride removal is optimized. Laboratory analysis or pilot studies shall be

conducted to assure the optimal coagulation process design.

b. pH adjustment. The pH adjustment step of pretreatment must result in the optimal pH level for the individual desalination system. After coagulants have



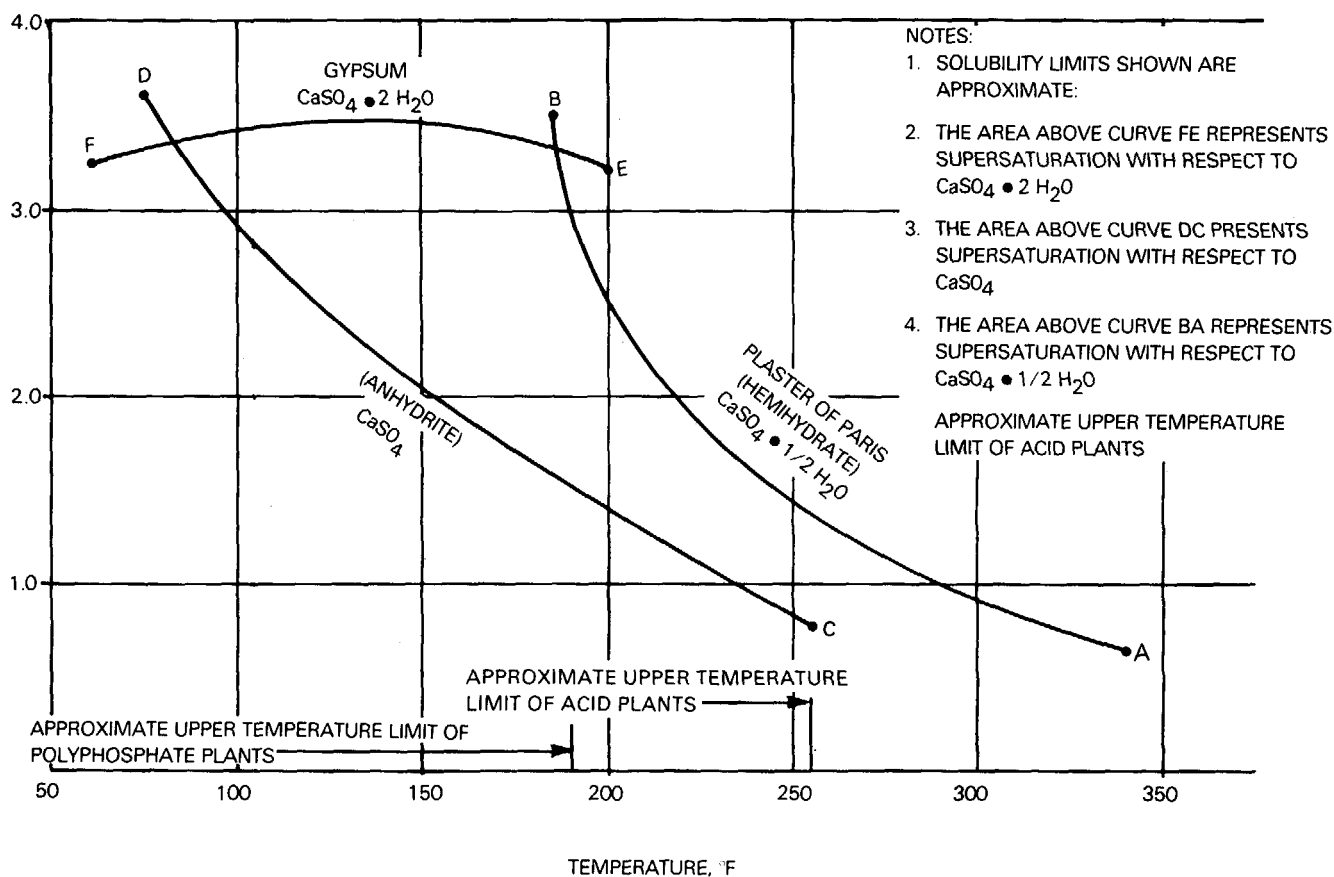
Source: U.S. Army Corps of Engineers

Figure 5-1. Pretreatment techniques.

been added, the pH is often changed significantly. In most cases, the pH must be returned to a neutral or a slightly acid level. Adjustment chemicals to lower the pH include carbon dioxide, sulfuric acid, and hydrochloric acid. Carbon dioxide should not be used for pH adjustment of lime addition systems because of the previously mentioned scaling problem associated

with lime pretreatment. Sulfuric acid should not be used for pH adjustment of systems where the resulting increase in sulfate salts can cause scaling in the desalination system. Fluoride removal will be hindered, if the pH is reduced below 7.0.

c. Scale inhibition. The formation of scale



Source. American Institute of Chemical Engineers

Figure 5-2. Approximate concentration factor limits for calcium sulfate in sea water.

limits the efficiency of product water recovery during plant operation. The precipitation of calcium carbonate, magnesium hydroxide, and calcium sulfate can be prevented through the addition of scale-inhibiting chemicals. Two scale-inhibiting chemical types are commonly used: polyphosphates and polyelectrolytes. The most commonly used scale inhibitors are polyphosphate chemicals. Polyphosphates lose their effectiveness above 190 degrees Fahrenheit, which limits upper operating temperatures. To prevent the formation of scale within desalination systems, polyphosphate-based chemicals are the best general purpose additive. The most commonly used polyphosphate compound is sodium hexametaphosphate. Polyelectrolytes or organic polymers are relatively new scale inhibitors. The use of polyelectrolytes in potable water shall be in accordance with paragraph 7 of AR 420-46.

5-3. Degasification and deaeration. The removal of dissolved gases from a feed water can be accomplished in one of two ways. The dissolved gas may be stripped out with another gas, or the dissolved gas may be stripped out with water vapor. A forced draft degasification tower will remove nonatmospheric gases. This is done by blowing air up through a tower of packing. The water to be degasified is then sprinkled over the packing. When full deaeration is required to prevent the interference of oxygen and nitrogen with water vaporization or flashing, steam or water vapor must be used as the stripping gas. On high-temperature distillation systems, a steam deaerator may be used. On most distillation desalination systems, the only economical method of deaeration the water is to lower the pressure with a vacuum pump or venturi eductor or ejector to produce enough water vapor to strip away all dissolved gases. There are two basic designs for water distribution in deaerators. A design that sprays the water in the deaerator vessel will usually create the most complete deaeration. The other commonly used design involves cascading the water over trays. While the internal design of this deaerator is prone to short circuiting and incomplete deaeration, it is more compact and requires no pressure to operate the sprayers.

5-4 Filtration with granular media. Before the filtration is designed, the possibility of use of wells/infiltration galleries shall be evaluated. Filtration is necessary when the desalination process requires a low level of particulate material. Primary filtration with granular media removes particulate materials left after lime, coagulants, or other chemicals have been added to the feed waters. Single-or dual-media filtration

systems are generally used. In some cases, mixed-media filtration may be necessary. Filters may use either pressure or gravity flow methods.

a. Single-media filtration. Single-media filtration consists of one media. This media is often small-grained silica sand; however, anthracite may be used after lime and lime-soda softening. Some desalination pretreatment systems use an alternate media such as greensand to remove iron compounds. Diatomaceous earth media is not recommended for primary filtration because of its characteristic high head loss and short run times.

b. Dual-media filtration. Dual-media filtration consists of two media with different specific gravities. The difference creates a two-layer separation effect. Use silica sand or greensand for one layer; use anthracite for the other layer. The use of dual media will allow larger quantities of material to be filtered and will reduce head loss during operation. The use of two media types will provide a good coarse-of-fine filtration process for desalination facilities.

c. Mixed-media filtration. When three media are used in filters, a better coarse-to-fine filtration pattern can be constructed. High-density silica sand, garnet, and anthracite are commonly used to provide the filter bed. The different media do not stratify completely. Instead, there is a small amount of intermixing among the different layers. This gradual change in media size provides a gradient from coarse to fine and creates a media flow pattern necessary to achieve a very low silt density index.

5-5. Secondary filtration. Secondary filtration is necessary to ensure that particulate material does not pass from the pretreatment systems into a membrane desalination process. Secondary filtration is used normally as a precautionary measure. Cartridge filters are commonly used. Ultrafiltration systems can be used as a process and precautionary measure.

a. Cartridge units. The necessary protection is most easily accomplished with cartridge filters. The cartridges are replaced easily, and the filter mesh can be sized to remove from 20-micron to 0.05-micron particles. Although some cartridge filters can be backwashed, most are replaced when head loss reaches excessive levels.

b. Ultrafiltration units. The newer process for secondary filtration is ultrafiltration. New

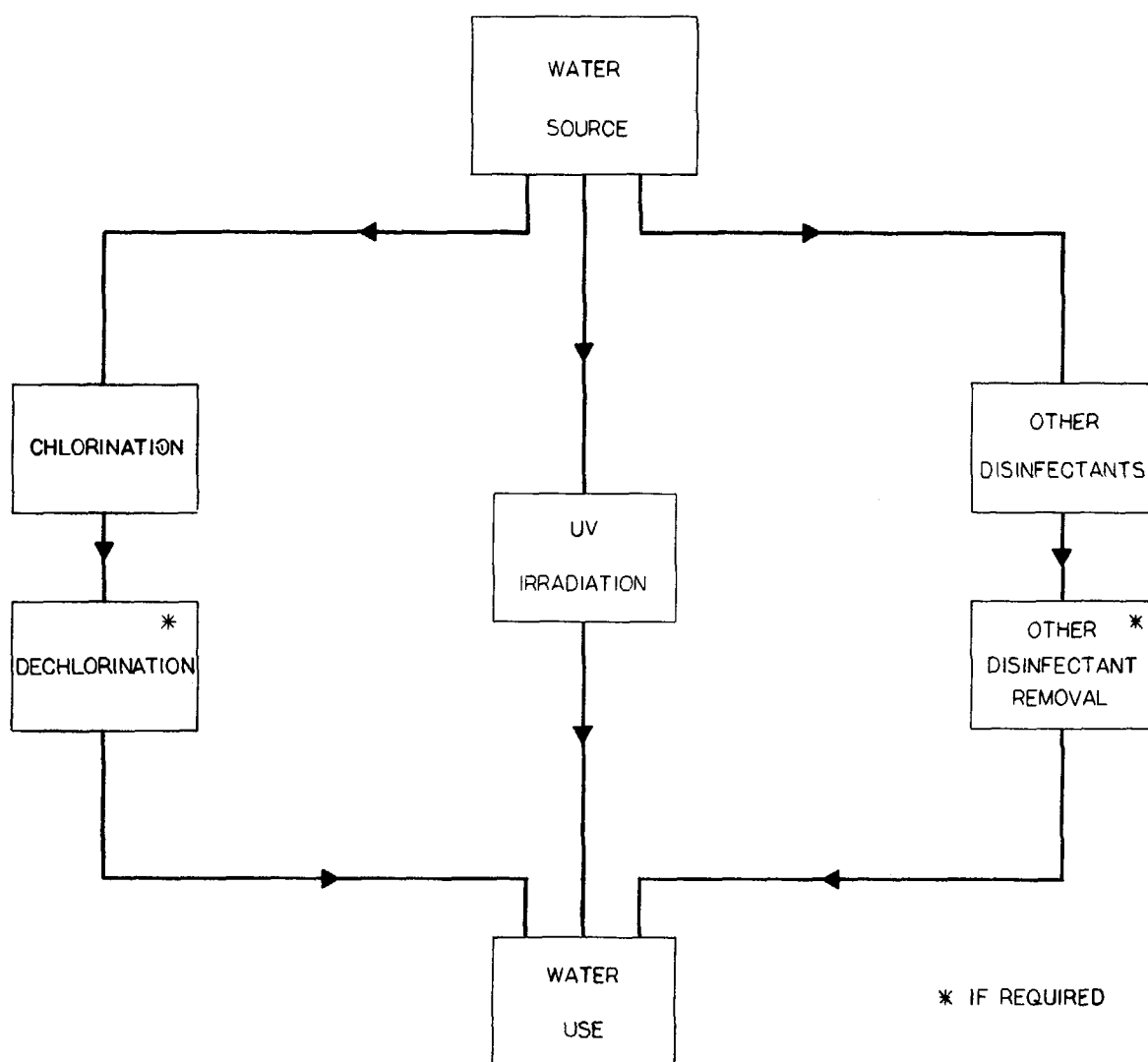


Figure 5-3. Disinfection alternatives.

materials provide 0.005-micron filtration in a stable, backwash operational unit. Some ultrafiltration units possess a salt-rejection capability, which reduces both the ultrafine particulate material and salt loading on membrane desalination processes. The ability to ensure particulate removal at 0.005-micron levels, as well as backwash capabilities, makes ultrafiltration an excellent secondary filtration technique.

5-6. Disinfection. Biological growth can seriously interfere with desalination surfaces and equipment. Cellulose acetate reverse osmosis membranes can be attacked by bacteria and require continuous disinfection application at the membrane surface. Disinfection of potable waters is required by TB MED 576 for sanitary reasons. Marine intake structures are particularly prone

to biogrowths. A strong biocide is usually needed to prevent extensive marine growths from fouling intakes, piping and storage facilities. An overview of disinfection alternatives can be found in figure 5-3. Chlorination is not advisable in the pretreatment process when organic contents are high.

a. Ultraviolet irradiation. One effective disinfection technique is ultraviolet irradiation.

Raw waters flow through a chamber where they are exposed to ultraviolet lamps. The resulting disinfection prevents bacterial destruction of cellulose acetate-based membrane systems and eliminates biofouling of polyaromatic-based membrane systems. Because polyaromatic fiber membranes are very susceptible to chemical oxidant attack, ultraviolet disinfection is the best disinfection technique for these systems.

b. Oxidants. The addition of chemical oxidants, such as chlorine, bromine, iodine, or ozone, can provide biological disinfection before membrane processes. The use of oxidants must be monitored carefully to keep the chlorine below 1.0 milligrams per liter of free chlorine residual that would even damage cellulose acetate membrane systems. For cellulose acetate membrane systems, a carefully monitored oxidant addition is the best technique for disinfection of biologically active feed waters. When biological and other organic materials are chlorinated, the resulting chlorine oxidation generates halogenated carbon compounds, such as the trihalomethane class of compounds. While the placement of chlorine disinfection upstream of coagulation or filtration will increase chlorine contact

time, which will increase the number of organisms destroyed, it will also increase trihalomethane formation. When an open intake requires optional disinfection as shown in figure 5-1 and chlorination is shown by pretreatment investigation to bring the trihalomethane content above 0.1 milligrams per liter, then no form of chlorine shall be used as a raw water disinfectant. The legal limit (per National Interim Drinking Water Regulations) for trihalomethanes in potable water effluents for communities and installations with an effective population of 10,000 or more is 0.1 milligrams per liter.

c. Dechlorination. When chlorine is used as a disinfectant, complete dechlorination of pretreated waters must occur before desalination in polyaromatic membrane systems. Dechlorination can be accomplished chemically through sulfite compound addition or passage through granular-activated carbon. Complete dechlorination and destruction of the chlorine residual by reducing compounds will ensure that chemicals do not attack these sensitive membrane systems. When a chlorinated water source must be used and complete dechlorination below 1.0 milligrams per liter as free chlorine is not possible, use distillation/condensation. When dechlorination is only economically practical to between 0.2 and 1.0 milligrams per liter as free chlorine, a cellulose acetate-based membrane system may be used.